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NELSON M. BLACHMAN

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The principal institution for electrical engineering education in Finland is the Helsinki University of Technology. The Technical Research Center of Finland is the leading organization in engineering research, and Nokia Electronics is the leading manufacturer of electronic equipment. This report discusses their activities--particularly in the field of communication engineering--and includes some remarks on the work going on elsewhere as well as on the general historical background.

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COMMUNICATION ENGINEERING IN FINLAND

Finland was a part of Sweden from the 12th century until 1809, when it became an autonomous Russian grandduchy, finally attaining its independence in 1917. In consequence of the 1939-1944 war with the USSR (and Germany) it lost 10% of its territory, including its corridor to the ice-free Arctic coast, and was forced to pay several hundred million dollars in indemnities to the Soviet Union. The result might have been still worse had Finland not succeeded in inflicting at least half a million Russian casualties, losing 78,000 dead itself and resettling 425,000 refugees from the ceded territory by sharing the remaining 130,000 square miles of Finland with them. This area is 72% forested, 9% covered by some tens of thousands of lakes, and 8% under cultivation. Forestry and agriculture account for 17% of Finland's employment. Out of the 4,700,000 total population, 453,000 live in the capital, Helsinki (Helsingfors), 127,000 in Tampere (Tammerfors), 124,000 in Turku (Åbo), and 120,000 in Espoo (Esbo), about which more is said below.

Finland is not, properly speaking, a part of Scandinavia but, rather, is linked with Scandinavia by its history and its membership in the UN's Nordic Council. Some 7% of the Finns are native speakers of Swedish, and this fraction possesses more than its proportionate share of Finland's wealth. The country has two official languages and, indeed, along the coast many towns and streets have both Finnish and Swedish names, as included above. Higher Education had originally been carried on entirely in Swedish, but in the 1930's a bilingual approach developed, and it is now conducted predominatly in Finnish.

All male citizens of Finland between the ages of 19 and 60 are liable for military service but, by the 1947 Treaty of Paris, its standing army may not exceed 34,400 men, its navy 4,500 men plus 10,000 tons, and its air force 3,000 men plus 60 aircraft, but no bombers are allowed. In addition, Finland has an agreement of friendship, cooperation, and mutual assistance with the USSR, which the latter uses to intervene in the Finns' domestic affairs. While they do their best to placate the Bear, setting up Soviet-Finnish friendship societies and engaging with the USSR and the other ComEcon countries, as well as with the West, in commercial trade and scientific exchange, the Finns obviously must ensure the utmost efficiency of their limited military resources in order to retain their independence. Finland expends only 5% of its state budget for defense and devotes an impressive 18% to education. It must continually perform a balancing act in order not to annoy its neighbor. Thus, having decided recently to buy 50 to 100 jet trainers from the British firm Hawker-Siddeley, it will soon be buying its first infantry surface-to-air missiles from the USSR--SAMs that had proven very effective in the Sinai desert.

During the week of 28 June 1976, I visited the Communication Laboratory of the Helsinki University of Technology (Helsingin Teknillinen Korkeakoulu, HTK) in order to learn something of the work going on in that vicinity in the field of communications and also to present five hours of lectures on some of my own work in communication theory. Prof. Seppo J. Halme, head of the Laboratory, was my host. He also arranged for me to see some of the work of the Telecommunications Laboratory of the Technical Research Center of Finland (Valtion Teknillinen Tutkimuskeskus, VTT). VTT's laboratories are principally located, like the HTK, in Espoo--six miles west of Helsinki--and also occupy some space in HTK's Electrical Engineering Department.

The particular part of Espoo (Esbo) where HTK and VTT are located is called Otaniemi (Otnäs), meaning "Tech Town," and mail will reach these institutions regardless of which of the four names is used. Near Otaniemi in Espoo is Kilo, where Nokia Electronics, Finland's largest supplier of professional electronic equipment, has built three beautiful buildings with a total floor area of 226,000 ft^2 on a 111-acre rolling, wooded site. I visited both this new plant and the older buildings of Nokia Electronics in Helsinki, seven miles to the east of Kilo. On a longer excursion I was taken to see the HTK laser satellite ranging station at Metsähovi (Skogstorp) in the commune of Kirkkonummi (Kyrsklätt), 18 miles southwest of Espoo, and to the 13.7-m HTK radiotelescope adjacent to it.

Electrical Engineering Education

Higher education in Finland began with the establishment of the University of Turku in 1640. In 1827 it was transferred to Helsinki, the new capital. Turku now has two private institutions, the Swedish-speaking Åbo Akademi, established in 1919, and the Finnish-language University of Turku, established in 1922. HTK began as a polytechnic school in 1840 and was elevated to the status of a university in 1908.

In 1956 Finland had eight universities, and they were concentrated in two cities--Helsinki and Turku. Since that time their number has risen to eighteen, located in nine cities. In five of these nine cities engineering education is offered: Espoo (=Helsinki), Tampere, Oulu, Turku, and Lappeenranta. Of these the first three offer specialization in electrical engineering, having admitted, respectively, 160, 105, and 40 students to that department in 1973. In addition, the University of Helsinki graduates about 10 physicists per year with a broad background in electronics, and the HTK Depart-

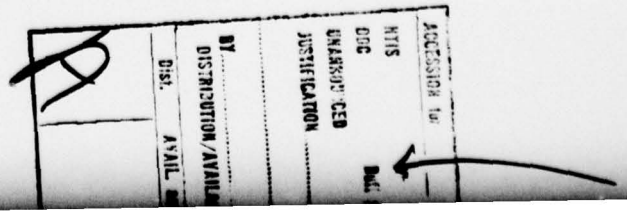
ment of Technical Physics graduates 20 to 40 physicists annually who specialize in electronics.

According to the report on "Electrical Engineering Education in Finland" presented by Halme to the IEEE Eurocon in 1974, 14% of the Finnish secondary-school graduates were going on to university-level institutions and, of those in such institutions, 12.5% or 7700 were studying engineering. The number of students in higher education is rising rapidly, and the number in engineering is expected to reach 11,000 by 1982. The 1965 law that decreed this growth also requires a teacher:student ratio of 1:8 and 269 ft^2 of space per engineering student. As a result, the facilities of the HTK in Otaniemi are quite spacious, although the requirements of the law have not been fully met in either respect.

Concern for the environment permeates Finland, and there is also a law requiring about 194 ft^2 of space per industrial employee, which makes for safe layouts in the newer factories, although it is very expensive. There is a general concern that new building designs should give due consideration to the terrain, the environment, and the comfort of the people who are to work in them. With such backing, Finnish architects have achieved outstanding results, as in the case of the Temppeliaukio Church in Helsinki, which should not be missed, and the HTK campus has a number of very aesthetic designs.

Tuition is free, but students coming from outside of university towns often need support, which comes in the form of state-guaranteed low-interest loans and, sometimes, from scholarships. In Finland, student corporations take care of student housing, health, and welfare as well as the usual activites, and they exert a strong influence on the operation of the universities. The active and talented student leaders of these corporations have established connections with all political parties in Finland, and, despite their lack of experience with the realities of the university, the economy, and society, they have come to play a dominant role in the formulation of educational policy--to the amazement of the mainly apolitical if also conservative faculty members. At the present stage, however, their wilder ideas seem to have been dropped.

Most graduate students in electrical engineering are paid an engineer's salary, but many others survive on smaller scholarships. The salaries come from teaching or research assistantships paid for by the Academy of Finland, industry, or other such sources, which the professor must find if his



laboratory is to flourish. Recently graduate students and engineering staff people have joined unions in an effort to ensure better support and living conditions.

The Students' Union sells copies of teachers' notes and visual materials on a nonprofit basis, this innovation having arisen at the time copying machines appeared on the campus--around 1967. Teaching materials include not only books published abroad (e.g., in English) but also Finnish textbooks, such as that of Halme and Ekberg on information theory, published by the Students' Union. Some efforts have been made at the HTK toward setting up four studios for closed-circuit TV teaching, to improve both the possibilities for visual aids and the efficiency of teaching, but CCTV teaching has turned into a political issue, and its future in Finland is uncertain at the moment.

Electrical Engineering

The study of electrical engineering in Finland began in 1883, and in 1941 a separate Department of Electrical Engineering was established in the HTK, which in 1969 moved from Helsinki to Espoo. In addition to Electrical Engineering, HTK has Departments of Technical Physics, Mechanical Engineering, Forest Products, Mining and Metallurgy, Civil Engineering, Surveying, Architecture, and General Sciences. It offers three degrees. The first, coming after five years of study, confers the title diploma engineer (*yli ins.* in Finnish) or architect; the advanced degrees, which require further study and a published dissertation, are the licentiate and doctorate in technology-(*tekn. lis.*, and *tekn. tri*, respectively, in Finnish). Forty percent of the diploma graduates continue their studies toward advanced degrees. In 1973, HTK admitted 831 students, bringing the enrollment to 4919 undergraduates and 568 graduate students with a total academic staff of 321 and a supporting staff of 424.

The Electrical Engineering Department, which occupies a 223,000-ft^2 building at Otakaari 5A (Otsvängen 5A) in Otaniemi, had 806 undergraduates and 106 graduate students, but the numbers of the latter are growing especially rapidly, being 230 in 1976 out of a total of 800 in the HTK.

The HTK Electrical Engineering Department is divided into five groups of laboratories, which carry out its teaching and research:

Electromagnetism
- Basic Electromagnetics and Measuring Techniques Laboratory
- Electron Physics Laboratory
- Radio Laboratory

Electronics
- Applied Electronics Laboratory
- Digital Electronics Laboratory

Communication Engineering
- Telecommunication Switching Laboratory
- Communication Transmission Laboratory
- Acoustics Laboratory

Control Engineering
- Systems Theory Laboratory
- Control Engineering Laboratory

Power Engineering
- Power Systems Laboratory
- Electrical Machinery Laboratory
- Power Electronics and Illumination Engineering Laboratory

In 1974, 20% of HTK's EE students were specializing in digital electronics, 19% in applied electronics, 12% in power engineering, 11% in control engineering, 8% in telephone engineering, 7% in communication engineering, 6% in radio engineering, 4% in electron physics, and smaller numbers in several additional specialties, but the distribution fluctuates from year to year on account of changing student interests and anticipated employment opportunities. Finland has about 2500 diploma electrical engineers, but the demand exceeds the supply, as Finnish work in this field is growing faster than the facilities for training.

Getting a diploma engineer's degree takes, in principle, 4 1/2 years--the first two being the basic course and the next two being divided between the major and minor professional courses. These are followed by at least half a year devoted entirely to a thesis, which, in fact is usually done as an employee in an industrial, government, or university laboratory. Graduation requires 180 credits (each representing 40 hours' work), of which 13 are in further optional subjects, and the final examination for the diploma may be taken whenever the student feels ready--sometimes a couple of years after completion of the other requirements. Thus, the average time to graduation exceeds five years. During the summers between academic years students usually get jobs that will give them practical experience

and training in their field.

Having studied mathematics, natural science (mainly physics), introductory electrical and mechanical engineering, etc., during the first two years, the student is given the "fundamental package" in the first half of the third year, which includes electrical power engineering, control engineering, electronics, electronics laboratory, electrical physics, and communication engineering. Altogether the Electrical Engineering Department offers some 50 subjects, from bioelectronics to remote sensing and electric space heating.

HTK Communication Laboratory

The Communication Laboratory of the HTK Electrical Engineering Department carries on teaching and research in communication theory, radio communications, channel charaterization, network synchronization, and optical communications. Its head, Prof. Seppo J. Halme, got his PhD from MIT in 1970 after earning his first two degrees at the HTK. He has been very active in a wide range of research --from identification problems in control engineering to optical-fiber communications and laser satellite ranging.

The Finnish Engineering Society INSKO offers many short courses for engineers, and Halme has served as chairman for courses on "Foundations of Digital Transmission," "Community Antenna (CATV) Systems," "Entertainment Electronics," and "Radio-Link Engineering," as well as lecturing in many others. He participates in the IEEE, URSI, and in Finnish engineering organizations. Halme is also a member of VTT advisory boards. He received the Finnish Academy Fellowship forSenior Scientists for the 1976-77 academic year, which is well deserved, as he is a man of great energy and dedication to progress for his country--a subject about which he is very plainly spoken. Under the fellowship Halme is working on optical-fiber communication and is completing the reports on and testing of the satellite laser system described below.

The curriculum of the Laboratory is distinguished from what is found in many such institutions by its including the basic principles of traffic theory and switching in addition to the usual theory and practice of communication engineering.

The Communication Laboratory is involved in four research projects--three of which are supported by the Post and Telegraph Administration of Finland (PTT) (Post- ja Lennätinhallitus). One of these is a study of selective fading at

6.7 GHz along the 49-km line-of-sight path from Tammela to Erkylä by analysis of hundreds of thousands of photographs of the received-pulse envelopes resulting from the transmission of short carrier pulses. The photographs are projected, viewed by a TV camera, processed by a Nova computer, and stored on magnetic tape for use in connection with programs for determining the optimum receiver. Perparations have been made for adding chirp to the transmitted pulses.

Another research project involves the construction of laboratory equipment for the comparison of various methods of synchronizing data communications. The prototype synchronization unit involves a voltage-controlled oscillator with a stability of 10^{-9}/day, and additional units to evaluate the whole system are under construction. This work is related to the Finnish part of the Nordic Data Network, for which Ericsson, Nokia, and ITT equipment is to be delivered between 1978 and 1980. It is to be fully digital, with many advanced features, including packet switching.

The third project is intended to gain experience with optical glass-fiber communications. A multimode step-index fiber (Hytran 100, of 85-μm diameter and 82-dB/km attenuation) made by Pilkington Brothers Ltd. has been set up with a laser-diode transmitter (SG 2001 and LOC C 30108 for 50 kbit/sec and 2 Mbit/sec, respectively, both with 20--s pulses) and avalanche photodiode receiver and is being upgraded for higher-speed transmission. The group has also obtained a CW laser diode from Laser Diode Laboratories, Inc. An electron microscope is employed in investigating the best means of joining fibers to one another and to other devices. A Nordic organization, Nordforsk, has set up a working group on optical-fiber communication and is making plans for drawing low-attenuation fibers in Trondheim, Norway, in Stockholm, Sweden, and perhaps in a year or two in Espoo, Finland, as well. The HTK Communication Laboratory is developing a capability for measuring their transmission characteristics as well as those of other manufacture, including Corning. Finland has a very high proportion of telephones per capita (35.8 per 100 population) and may well decide to install optical-fiber transmission systems in the southern, more densely populated part of the country.

The fourth research project is the satellite-ranging laser system, which is a joint effort of the Communication Laboratory and the Geodetic Institute, partially financed by the Academy of Finland (an organ of the State) and Suomen Tiedeskatemia (Finnish Academy of Sciences, a nongovernmental body of scientists and representatives of the humanities.)

The system is located in Metsähovi, 150 m east of the HTK Radio Laboratory's 13.7-m radiotelescope (see "Radio Research at Helsinki University of Technology," by D.K. Cheng, ESN-31-2: 43-45). The assembly and testing of the system were completed in November 1976, and it was found to have an accuracy of 0.8 nsec on the 200-m test line. Cloudy weather, however, had delayed ranging on a satellite, which was to be tried in February 1977 with the arrival of clear, cold weather. Centre National d'Etudes Spatiales, Paris, is providing predictions of satellite passes.

With the cooperation of the Geographical Survey Office of Sweden, the satellite-ranging laser system is intended to establish geodetic ties between Finland, Sweden, and other countries and to study crustal movements, especially of the lithospheric blocks. It uses a 694.3-nm Q-switched ruby laser with 1-J pulses of 20-nsec duration and 4-mrad uncollimated beam width. The telescope is a sidereally driven astronomical unit with 630-mm paraboloidal mirror and programmed tracking mount, equipped with an optical filter of 3-nm bandwidth and 0.7 transmission. The RCA C31034 photomultiplier has a quantum efficiency exceeding 10%, with background and dark currents limited to allow daylight operation. The time-interval counter has a 1-nsec resolution.

A Korad K1 laser, made in the US, is used with a 100 x 10-mm ruby rod having antireflection coating, pumped by a helical flashlamp and controlled by a Lasermetrics Q switch with KD*P Pockels cell. The power supply charges a 400-mf Maxwell capacitor to 5 kV up to six times per minute. Because of the high latitude (60° 13.1'), the equatorial telescope mount is almost as good as an azimuth-elevation mount, and it is convenient for stellar calibration. The telescope, of 173-cm focal length, was constructed at the Institute of Optical and Astronomical Research in Tuorla, southeast of Turku, and aluminized at the University of Uppsala, Sweden. The gearing and completion of the mount were carried out by the VTT in Espoo. There is also a Celestron 8-inch finder telescope.

Halme has investigated the factors affecting range estimation in satellite laser systems for both optimum and non-optimum receivers, and he obtained a Chernoff-type bound on the global error performance (EUROCON, 1974). Various kinds of pulse-epoch estimators have been studied analytically and experimentally, including the constant-fraction discriminator, half-area, and mean-square curve-fitting algorithm. Lic. Tech. A.B. Sharma has found the best measure of the epoch of a variable-sized pulse to be half way up the integrated photomultiplier

output. Hence, a Nanofast time-interval counter (536B with M/2 halfmax detection unit) is used to interpolate to 0.1 nsec the round-trip time of the laser pulse when returned by satellite-borne corner reflectors.

Timing (to make possible simultaneous observations with other stations) is based on a Hewlett-Packard quartz-clock system (HP 105B, 115 CR) synchronized to better than 1 μsec with universal time via a Loran-C frequency-comparison receiver, which is tuned to the NATO Loran station at Sylt. This receiver was built by the HTK Laboratory of Electrical Measurements. The time, telescope orientation, weather, and time delay will all be punched automatically on paper tape for later processing. This is a quite ambitious project, involving techniques from many different fields, and it is providing a great deal of training as well as the possibilities for international scientific cooperation.

A previous research project had developed a theory of attenuation on satellite links due to rain as a function of rain-gauge data, and its predictions were found to agree satisfactorily with available observations on the assumption of exponential spatial correlation of rain intensity.

Technical Research Center of Finland

Communications research in Finland, as discussed by Halme in the *IEEE Transactions on Communications (COM-22*, 1479-1481, Sept. 1974), is concentrated at the HTK (in its Telecommunication Switching, Communication, and Radio Laboratories), the Technical Research Center of Finland (in its Telecommunication Laboratory); the Telegraph and Radio Departments of the Post and Telegraph Administration; Nokia Electronics Co.; the EE Department of the University of Oulu; and in the Helsinki Telephone Company's Research Institute.

The Technical Research Center of Finland (Valtion Teknillinen Tutkimuskeskus, VTT) was established under the Ministry of Commerce and Industry in 1942 to carry out technical research, development, and testing as well as dissemination of technical information. It has 1500 employees (35% of them university graduates) and 32 laboratories working in various technical fields, nearly all located in Espoo. There it has 520,000 ft^2, including some space in the HTK EE Department, but there are other VTT laboratories in Helsinki, Tampere, and Oulu, with a total of 105,000 ft^2 of space. Its operating expenses amount to about $18 million per year, which comes in roughly equal parts from the state and from research contracts. The outside work that it does for the government and for industry

is in some cases confidential. To assess the importance of such an organization to Finland, multiply its size by fifty, the ratio of the US population to that of Finland. Also, note that Finland's gross national product amounts to about $24 billion. This is $5100 per capita as compared with $7060 for the US and $3840 for the UK in 1975.

The VTT focuses on engineering research to support industrial product development and to protect the interests of consumers, society, and the environment. In addition, it carries out fundamental research in order to maintain technical preparedness, develops methods and equipment for the-testing and control of materials, and maintains measurement standards. Among its larger goals have been the alleviation of Finland's trade deficit by accelerating the development of new products, the introduction of greater automation to relieve the shortage of labor, and the search for new energy sources. It also serves as a headquarters for Finland's scientific attaches, distributing their reports to industry and to research institutes, and organizing conferences for them and lending the materials they collect. In addition, it acquires documents directly from abroad, e.g., from the US and Canada through the Scandinavian Documentation Center in Washington.

The VTT is organized along both project and technical-field lines. Its fields are grouped into three research Divisions: Building Technology and Community Development, Materials and Processing Technology, and Electrical and Nuclear Technology. In addition, there are a General Division and a Technical Information Service. The VTT's activities are supervised and guided by a Board appointed by the Ministry of Commerce and Industry; there are also specialized advisory committees that assist the research divisions, the laboratories, and the Board.

The Division of Electrical and Nuclear Technology, headed by Research Director Prof. Veikko Palva, comprises seven Laboratories: the Semiconductor Lab. (research on electic and magnetic properties of semiconductor materials, and semiconductor technology); Reactor Lab. (material, process, and reactor-physics research based on the use of a PWR and radioisotopes, and development of measuring techniques); Electrical Engineering Lab. (electrical measurements; power, control, and systems engineering; and reliability analysis of engineering systems); Telecommunication Lab. (telecommunication R&D, data processing, radar, and testing of electronic equipment and components); Nuclear Engineering Lab. (research on reactor-core fuel management, reactor dynamics, and safety); Electronics Lab. in Oulu (industrial

instrumentation and other electronic research); and Biomedical Engineering Lab. in Tampere (research on and testing of equipment and systems for hospital instrumentation, and hospital automation).

The Telecommunications Laboratory, whose director is Prof. Esko Heikkilä, in 1974 had 53 employees, half of whom were university graduates, and a budget of about $6 1/2 million, 69% of which was from external financing and the rest from direct state support. It is composed of four sections: the Radio Section under Veli Santomaa, associate director of the Laboratory, the Telephone Section under Dr. Jan Ekberg (who is a part-time teacher at the HTK), the Testing Section, and the General Section.

The Radio Section, from which the entire Telecommunications Laboratory sprang, is now devoted to research and development in electromagnetic propagation (including EMP generation and coupling into telephone lines), antennas (now the section's biggest activity-including a phased array for ships, an electronically steerable traveling-wave antenna, and a log-periodic monopulse direction-finding antenna at the time of my visit), radio equipment (including 160-MHz police radiotelephone system planning and military DF systems), radar (originally 100% of the Section's work and now 20%), and special measuring instruments (including passive acoustic methods for anticipating the rupture of pressure vessels).

The Telephone Section is working on the emulation of various manufacturers' call-routing minicomputers, the choice between IBM's and ITT's programming languages for telephone systems, planning for the transmission of data along with speech on the telephone network, the construction of an error-rate analyzer, the simulation of telephone exchanges and networks, optical-fiber transmission, the construction of small telephone exchanges for the military, and on the encryption of speech.

Their approach to this encryption is based on Ekberg's 1973 HTK doctoral dissertation, "On the Properties of Random Pulse Position-Code Modulation, a System Especially Developed for the Enciphering of Speech Signals," which is Publication Number 1 (71 pp.) for the VTT's Division of Electrical and Nuclear Technology. There he both theoretically and experimentally studied systems such as delta-modulation with truly random intervals between sampling times. Each sample is represented by the same sort of short pulse, whose information (0 or 1) is carried by its timing in relation to a secret deterministic sequence of binary digits that is reinitiated at the transmitter and receiver each time a pulse is sent or received. These

pulses are not sent at exactly the random sampling times but at a slightly later time at which the secret sequence contains the digit (0 or 1) resulting from sampling the voice waveform. Thus, the receiver does not need to generate the sequence of random sampling intervals. Ekberg investigated the characteristics and the performance of systems of this sort, including their increased bandwidth requirements, increased susceptibility to noise and interference, cryptanalytic security, and resistance to jamming by a periodic pulse train, which benefits from the random timing. The scheme is not highly sophisticated, but it was found to yield a high degree of secrecy without the need for long-term synchronization, and it provides a basis upon which to build a capability in this field.

The Testing Section of the Telecommunications Laboratory engages in research on components, in environmental and electronic testing of components and systems, and in standardization work. The General Section takes care of procurement, workshops, supply, storage, and work space.

Nokia Electronics

Oy Nokia Ab is one of the biggest corporations in Finland, with nearly 14,000 employees and with 1974 sales of about $400 million, of which 28% represented exports. It consists of four divisions: (1) Pulp, paper, and power with 2000 employees and with mills and factories in the boroughof Nokia and in Ikalinnen, (2) the Finnish Rubber Works, with 5000 employees, having factories in NOkia and in three other towns, (3) the Finnish Cable Works, with 5000 employees, located in Helsinki, Pikkala, Tampere, and Vantaa, and (4) Nokia Electronics, which originated in 1960 as a department of the Finnish Cable Works and was organized as a separate division in 1967. In 1974 its total sales came to about $45 million, of which 17% represented exports. Nokia, in addition, owns sales offices in Sweden, Netherlands, US, and USSR.

Nokia Electronics, in turn, with a total of 2400 employees in Helsinki, Kilo, Oulu, and Tampere, consists of five departments: (1) Telecommunications; (2) Industrial Automation; (3) Data Processing; (4) Special Electronics; and (5) the Research Department, which serves the other departments and also does research to order--mainly in telecommunication, data processing, and automation. These respectively produce (1) FDM and PCM multiplexing and coaxial-line equipment, UHF and microwave radio links for FDM-FM and for PCM radiotelephone systems, and 300- to 19,200-bit/sec data modems; (2) automation systems for the pulp and paper industry, control systems for both nuclear and conventional thermal power generation, telecommunication

and remote-control systems for electricity and gas distrubution, etc.; (3) minicomputer systems and computer-terminal systems, as well as measuring instruments, such as a multichannel pulse analyzer; and (4) automation, control, and simulation systems for military, navigational, traffic, and nuclear-physics applications. Their Autonavigator system uses a 3-cm and a 10-cm radar in conjunction with a computer storing a map of the route through the Finnish archipelago to provide ships with information as to their positions, speeds, and courses to with in 25 miles and 15° as well as the distance to the next turning point. Current military work includes an early-warning radar and a laser ranging device.

Under license from E-Systems (FortWayne, Indiana), Nokia Electronics is manufacturing AN-PRC-77 narrowband FM tactical communication sets for batallion-level use in the 27-to-73-MHz band with a 50-kHz channel spearation, yielding 920 available channels, selected by means of a frequency synthesizer. This communication system was chosen on account of the reliability that it had demonstrated in Vietnam.

Nokia Electronics has to meet rigorous environmental requirements not only in northern Finland but also in Siberia, where its UHF and microwave radio links must withstand 100°C variations in temperature. On the other hand, NOkia has close ties with the US and France, as its Computer Department represents Honeywell Information Systems, Inc., for all of its computers and data processing equipment in Finland through Honeywell's French subsidiary Compagnie HoneywellBull. It also handles other computer manufactures' sales and rental, and it provides data-processing services for Nokia and for its clients through its computer centers in Kilo, Tampere, and Helsinki.

Minicomputers are incorporated into the more advanced control systems and communication networks built by the Industrial Automation Department for such purposes as airline and railway reservations, radio and television program distribution, remote control of water supply and pumping stations, control of all processes in the paper and pulp industry (including pollution), and functions of local and national government.

In the smaller control systems, programmable central logic is used instead of minicomputers. Numerous Nokia mini- and microcomputers, however, are used in some of the larger systems, such as their computer-terminal networks for banking, for manufacturing, and for retailing. These systems are modular and permit many different options. In some cases, a large (Honeywell) computer is used to process the output tapes generated

by these networks, but digital CRT displays and printed output are available for direct use. In addition, Nokia Electronics makes a punched-tape reader that operates at the remarkable speed of 2500 characters per second.

The Nokia multichannel analyzers are used not only to produce histograms of the distribution of pulse heights for gamma-ray spectroscopy--the original motivation---ut also analyses of the time intervals between pulses or the variation in pulse density with time for a multitude of purposes both in physics and in medicine, including cardiac output, total blood volume (from a single radiocardiogram), ECG, and EMG. These desktop analyzers can also provide the correlograms, cross correlograms, and Fourier transforms of their inputs, which may be sorted into as many as 8192 memory registers. Nokia has recently granted a license for their manufacture in Poland.

Nokia Electronics also makes light-panel displays for sporting events, advertising, and the like, using 5 x 7 arrays to form the characters and incorporating whatever data processing, time, and other features are appropriate, with the possibility of direct relaying to news media. NOkia Electronics makes all of its own one- and two-sided printed-circuit boards, which are laid out by computer-aided design, and it also sells such boards to other organizations.

The equipment built by Nokia Electronics is very pleasing in appearance as well as up-to-date in conception and design. Moreover, the Nokia buildings in Kilo are spacious and make excellent use of light and color in their design and layout.
Great care was taken there to avoid adversely affecting the enivronment and to provide comfortable working conditions; there is even a day-nursery for employees' children.

Other Finnish Centers of Communication Research

In addition to the HTK, VTT, and Nokia Electronics, as mentioned earlier, Finnish research on communications is conducted in the Telephone Laboratory of the PTT, the Institute of Telecommunications in the Electrical Engineering Department of the University of Oulu, and the Research Institute of the Helsinki Telephone Company.

The work at the University of Oulu is concerned mainly with PCM and with transmission techniques for telephony in the special conditions of northern Finland. A small amount of work, supported by industry and by telephone companies, is

being done at the Tampere Universityof Technology on the operating characteristics of specific telephone systems. The PTT and Helsinki Telephone Company work is largely of a developmental nature, dealing with such techniques as time-division multiplexing and switching, with traffic theory, and with radio propagation.

In the Finnish telephone network, the PTT serves about one-third of the subscribers, and there are 63 independent telephone companies, public and private, serving the remaining two-thirds. Because of the profusion of small companies, some have served as testing grounds for international equipment manufacturers' new designs. Unlike the situation in Britain, where four major manufacturers compete in developing the best solution to a Post Office problem and the best solution is then cross-licensed and manufactured by all four, the 64 Finnish telephone organizations buy from the 20-odd suppliers with little coordination in their approaches. The Finnish level of service is nonetheless high and the cost low.

In summary, it can be seen that Finland, though small and a bit isolated by its geography, is active in the field of communications and is keeping abreast of developments throughout the world. Its history and its proximity to the USSR necessitate its constant military preparedness within tight limitations imposed by treaty, and so it is obliged to be very efficient in the use of its resources. It deserves great credit for its achievements.

I was very favorably impressed not only by the Finnish accomplishments in electronics, architecture, and international relations mentioned above, but also by Finnish hospitality and cuisine. As a guest of the HTK I was provided a very comfortable furnished apartment in Otaniemi, which was complete even to maid service, radio, and TV. With Tallinn, Estonia, only fifty miles to the south across the Gulf of Finland, it was even possible to see a little through the Iron Curtain. The guest book of this apartment attested to the breadth and frequency of HTK contacts with visitors from both Western and Eastern Europe as well as from America.

Additional material on Finland can be found on pp. 18-19 of the ONRL 30th Anniversary Collection of ESN articles ("Finnish Scientific and Educational Institutions," by J.S. Smart, from ESN 21-2) and ONRL Technical Reports 98-56 (on limnology and oceanography), 37-56 (psychology), and 1-57 (solid-state physics).